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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No. RAVI0009

First Inventor or Application Identifier Sigmund

Title On the Fly Generation of Multimedia Code for Image...

Express Mail Label No. EL540885913US

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APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. * Fee Transmittal Form (e.g., PTO/SB/17)
(Submit an original and a duplicate for fee processing)
2. Specification [Total Pages 34]
(preferred arrangement set forth below)
 - Descriptive title of the Invention
 - Cross References to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to Microfiche Appendix
 - Background of the Invention
 - Brief Summary of the Invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claim(s)
 - Abstract of the Disclosure
3. Drawing(s) (35 U.S.C. 113) [Total Sheets 1]
4. Oath or Declaration [Total Pages 2]
 - a. Newly executed (original or copy)
 - b. Copy from a prior application (37 C.F.R. § 1.63(d))
(for continuation/divisional with Box 16 completed)
 - i. DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

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5. Microfiche Computer Program (Appendix)
6. Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
 - a. Computer Readable Copy
 - b. Paper Copy (identical to computer copy)
 - c. Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. Assignment Papers (cover sheet & document(s))
8. 37 C.F.R. § 3.73(b) Statement Power of (when there is an assignee) Attorney
9. English Translation Document (if applicable)
10. Information Disclosure Statement (IDS)/PTO-1449 Copies of IDS Citations
11. Preliminary Amendment
12. Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
13. * Small Entity Statement(s) Statement filed in prior application, (PTO/SB-09-12) Status still proper and desired
14. Certified Copy of Priority Document(s)
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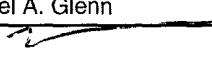
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Docket Number (Optional)
RAV10009Applicant, Patentee, or Identifier. **Sigmund**

Application or Patent No. _____

Filed or Issued: **Herewith**Title: **On The Fly Generation of Multimedia Code for Image Processing**

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 Docket Number (Optional)
 RAVI0009

Applicant, Patentee, or Identifier: Sigmund

Application or Patent No.: Unassigned

Filed or Issued: Herewith

Title: On The Fly Generation of Multimedia Code for Image Processing

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ULRICH SIGMUND

NAME OF INVENTOR

Signature of inventor

NAME OF INVENTOR

NAME OF INVENTOR

Date

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5 **ON THE FLY GENERATION OF MULTIMEDIA CODE FOR
IMAGE PROCESSING**

Background of the Invention

10 **Field of the Invention**

The invention relates to the processing of multimedia data with processors that feature multimedia instruction enhanced instruction sets. More particularly, the invention relates to a method and apparatus for generating processor instruction sequences for image processing routines that use multimedia enhanced instructions.

15 **Description of the Prior Art**

In general, most programs that use image processing routines with multimedia instructions do not use a general-purpose compiler for these parts of the program. These programs typically use assembly routines to process such data. A resulting problem is that the assembly routines must be added to the code manually. This step requires high technical skill, is time demanding, and is prone to introduce errors into the code.

5 In addition, different type of processors, (for example, Intel's Pentium I w/MMX
and Pentium II, Pentium III, Willamette, AMD's K-6 and AMD's K-7 aka. Athlon)
each use different multimedia command sets. Examples of different multimedia
command sets are MMX, SSE and 3DNow. Applications that use these
multimedia command sets must have separate assembly routines that are
10 specifically written for each processor type.

At runtime, the applications select the proper assembly routines based on the
processor detected. To reduce the workload and increase the robustness of the
code, these assembly routines are sometimes generated by a routine specific
15 source code generator during program development.

One problem with this type of programming is that the applications must have
redundant assembly routines which can process the same multimedia data, but
which are written for the different types of processors. However, only one
20 assembly routine is actually used at runtime. Because there are many
generations of processors in existence, the size of applications that use
multimedia instructions must grow to be compatible with all of these processors.
In addition, as new processors are developed, all new routines must be coded for
these applications so that they are compatible with the new processors. An
25 application that is released prior to the release of a processor is incompatible

5 with the processor unless it is first patched/rebuilt with the new assembly routines.

It would be desirable to provide programs that use multimedia instructions which
are smaller in size. It would be desirable to provide an approach that adapts such
10 programs to future processors more easily

Summary of the Invention

In accordance with the invention, a method and apparatus for generating
assembly routines for multimedia instruction enhanced data is shown and
15 described.

An example of multimedia data that can be processed by multimedia instructions
are the pixel blocks used in image processing. Most image processing routines
operate on rectangular blocks of evenly sized data pieces (e.g. 16x16 pixel
blocks of 8 bit video during MPEG motion compensation). The image processing
20 code is described as a set of source blocks, destination blocks and data
manipulations. Each block has a start address, a pitch (distance in bytes
between two consecutive lines) and a data format. The full processing code
includes width and height as additional parameters. All of these parameters can
25 either be integer constants or arguments to the generated routine. All data
operations are described on SIMD data types. A SIMD data type is a basic data

- 5 type (e.g. signed byte, signed word, or unsigned byte) and a number or repeats
(e.g. 16 pixels for MPEG Macroblocks). The size of a block (source or destination) is always the size of its SIMD data type times its width in horizontal direction and the height in vertical direction.
- 10 In the presently preferred embodiment of the invention, an abstract image generator inside the application program produces an abstract routine representation of the code that operates on the multimedia data using SIMD operations. A directed acyclic graph is a typical example of a generic version. A translator then generates processor specific assembly code from the abstract representation.
- 15

Brief Description of the Drawings

FIG. 1 is a block diagram of a computer system that may be used to implement a method and apparatus embodying the invention for translating a multimedia routine from its abstract representation generated by an abstract routine generator inside the application's startup code into executable code using the code generator.

5

Description of the Preferred Embodiment

In Fig.1 the startup code 11 of the application program 13, further referred to as the abstract routine generator, generates an abstract representation 15 of the multimedia routine represented by a data flow graph. This graph is then

10 translated by the code generator 17 into a machine specific sequence of instructions 19, typically including several SIMD multimedia instructions. The

types of operations that can be present inside the data flow graph include add,

sub, multiply, average, maximum, minimum, compare, and, or, xor, pack, unpack

and merge operations. This list is not exhaustive as there are operations

15 currently performed by MMX, SSE and 3DNow for example, which are not listed.

If a specific command set does not support one of these operations, the CPU specific part of the code generator replaces it by a sequence of simpler instructions (e.g. the maximum instruction can be replaced by a pair of subtract and add instruction using saturation arithmetic).

20

The abstract routine generator generates an abstract representation of the code, commonly in the form of a directed acyclic graph during runtime. This allows the creation of multiple similar routines using a loop inside the image processing code 21 for linear arrays, or to generate routines on the fly depending on user interaction. *E.g.* the bi-directional MPEG 2 motion compensation can be implemented using a set of sixty-four different but very similar routines, that can be generated by a loop in the abstract image generator. Or an interactive paint

5 program can generate filters or pens in the form of abstract representations
based on user input, and can use the routine generator to create efficient code
sequences to perform the filtering or drawing operation. Examples of the data
types processed by the code sequences include: SIMD input data, image input
data and audio input data.

10

Examples of information provided by the graphs include the source blocks, the target blocks, the change in the block, color, stride, change in stride, display block, and spatial filtering.

15 The accuracy of the operation inside the graphs can be tailored to meet the requirements of the program. The abstract routine generator can increase its precision by increasing the level of arithmetics per pixel. For example, 7-bit processing can be stepped up to 8-bit, or 8-bit to 16-bit. *E.g.* motion compensation routines with different types of rounding precision can be
20 generated by the abstract routine generator.

The abstract representation, in this case the graph 15, is then sent to the translator 17 where it is translated into optimized assembly code 19. The translator uses standard compiler techniques to translate the generic graph structure into a specific sequence of assembly instructions. As the description is very generic, there is no link to a specific processor architecture, and because it
25

5 is very simple it can be processed without requiring complex compiler
techniques. This enables the translation to be executed during program startup
without causing a significant delay. Also, the abstract generator and the
translator do not have to be programmed in assembly. The CPU specific
translator may reside in a dynamic link library and can therefore be replaced if
10 the system processor is changed. This enables programs to use the multimedia
instructions of a new processor, without the need to be changed.

Tables A-C provide sample code that generates an abstract representation for a
motion compensation code that can be translated to an executable code
15 sequence using the invention.

TABLE A

```
20 #ifndef MPEG2MOTIONCOMPENSATION_H
#define MPEG2MOTIONCOMPENSATION_H

#include "driver\softwarecinemaster\common\prelude.h"
#include "..\..\BlockVideoProcessor\BVPXMMXCodeConverter.h"

25   //
// Basic block motion compensation functions
//
class MPEG2MotionCompensation
{
30   protected:
    //
    // Function prototype for a unidirectional motion compensation
    routine
    //
35   typedef void (__stdcall * CompensationCodeType)(BYTE * source1Base,
int sourceStride,
                                BYTE * targetBase, short * deltaBase,
int deltaStride,
                                int num);
```

```

5
  //
  // Function prototype for a bidirectional motion compensation
routine
  //
10   typedef void (_stdcall * BiCompensationCodeType)(BYTE *
source1Base, BYTE * source2Base, int sourceStride,
                           BYTE * targetBase, short * deltaBase,
int deltaStride,
                           int num);

15

  //
  // Motion compensation routines for unidirectional prediction.
Each routine
20   // handles one case. The indices are
    // - y-uv : if it is luma data the index is 0 otherwise 1
    // - delta : error correction data is present (eg. the block
is not skipped)
    // - halfy : half pel prediction is to be performed in
25 vertical direction
    // - halfx : half pel prediction is to be performed in
horizontal direction
    //
30   CompensationCodeType      compensation[2][2][2][2];           //
y-uv delta halfy halfx
   BVPCodeBlock      * compensationBlock[2][2][2][2];

  //
  // Motion compensation routines for bidirectional prediction.
35 Each routine
    // handles one case. The indices contain the same parameters as
in the
    // unidirectional case, plus the half pel selectors for the
second source
40   //
BiCompensationCodeType      bicompensation[2][2][2][2][2];       //
y-uv delta halfly halffx halfy2 halfx2
   BVPCodeBlock      * bicompensationBlock[2][2][2][2][2];

public:
45   //
    // Perform a unidirectional compensation
    //
    void MotionCompensation(BYTE * sourcep, int stride, BYTE * destp,
short * deltap, int dstride, int num, bool uv, bool delta, int halfx,
50 int halfy)
    {
        compensation[uv][delta][halfy][halfx](sourcep, stride, destp,
deltap, dstride, num);
    }

55
  //
  // Perform bidirectional compensation
  //
60   void BiMotionCompensation(BYTE * source1p, BYTE * source2p, int
stride, BYTE * destp, short * deltap, int dstride, int num, bool uv,
bool delta, int halflx, int halfly, int half2x, int half2y)

```

```

5           {
10          bicompensation[uv][delta][half1y][half1x][half2y][half2x](sourcelp,
source2p, stride, destp, deltap, dstride, num);
}
10         MPEG2MotionCompensation(void);
~MPEG2MotionCompensation(void);
};

15 #endif

```

TABLE B

```

20 #include "MPEG2MotionCompensation.h"
#include "...\\BlockVideoProcessor\\BVPXMMXCodeConverter.h"

25 // Create the dataflow to fetch a data element from a source block,
// with or without half pel compensation in horizontal and/or
// vertical direction.
//
30 BVPDataSourceInstruction * BuildBlockMerge(BVPSourceBlock *
source1BlockA,
                                BVPSourceBlock * source1BlockB,
                                BVPSourceBlock * source1BlockC,
                                BVPSourceBlock * source1BlockD,
                                int halfx, int halfy)

35 {
    if (halfy)
    {
        if (halfx)
        {
            //
40 // Half pel prediction in h and v direction, the graph part
looks like this
            //
            //
            .--(LOAD source1BlockA)
            //
            //
45            .--(AVG) /
            //   / \ \
            //   /   \ `--(LOAD source1BlockB)
            // <--(AVG)   .--(LOAD source1BlockC)
            //   \   / \
            //   \   \ `--(AVG)
            //           / \
            //           \ `--(LOAD source1BlockD)
            //
55 return new BVPDataOperation
(

```

```
5             BVPDO_AVG,
       new BVPDataOperation
          (
            BVPDO_AVG,
            new BVPDataLoad(source1BlockA),
            new BVPDataLoad(source1BlockB)
          ),
10         new BVPDataOperation
          (
            BVPDO_AVG,
            new BVPDataLoad(source1BlockC),
            new BVPDataLoad(source1BlockD)
          )
        );
      }
20     else
      {
        //
        // Half pel prediction in vertical direction
        //
25       //           .--(LOAD source1BlockA)
        //           /
        // <--(AVG)
        //           \
        //           `--(LOAD source1BlockC)
        //
30       return new BVPDataOperation
          (
            BVPDO_AVG,
            new BVPDataLoad(source1BlockA),
            new BVPDataLoad(source1BlockC)
          );
        }
      }
35     else
      {
40       if (halfx)
        {
          //
          // Half pel prediction in horizontal direction
45       //           .--(LOAD source1BlockA)
          //           /
          // <--(AVG)
          //           \
          //           `--(LOAD source1BlockB)
          //
50       return new BVPDataOperation
          (
            BVPDO_AVG,
            new BVPDataLoad(source1BlockA),
            new BVPDataLoad(source1BlockB)
          );
        }
      }
55     else
      {
60       //
    }
```

```

5           // Full pel prediction
// 
// <--(LOAD source1BlockA)
// 
10          return new BVPDataLoad(source1BlockA);
}
}

MPEG2MotionCompensation::MPEG2MotionCompensation(void)
15         {
int yuv, delta, halfy, halfx, halfly, halflx, half2y, half2x;
BVPBlockProcessor * bvp;
BVPCodeBlock   * code;

20         BVPArgument * source1Base;
BVPArgument * source2Base;
BVPArgument * sourceStride;
BVPArgument * targetBase;
BVPArgument * deltaBase;
25         BVPArgument * deltaStride;
BVPArgument * height;

BVPSourceBlock * source1BlockA;
BVPSourceBlock * source1BlockB;
BVPSourceBlock * source1BlockC;
30         BVPSourceBlock * source1BlockD;
BVPSourceBlock * source2BlockA;
BVPSourceBlock * source2BlockB;
BVPSourceBlock * source2BlockC;
35         BVPSourceBlock * source2BlockD;

BVPSourceBlock * deltaBlock;
BVPTargetBlock * targetBlock;

40         BVPDataSourceInstruction * postMC;
BVPDataSourceInstruction * postCorrect;
BVPDataSourceInstruction * deltaData;

//
45         // Build unidirectional motion compensation routines
//
for(yuv = 0; yuv<2; yuv++)
{
    for(delta=0; delta<2; delta++)
50         {
            for(halfy=0; halfy<2; halfy++)
                {
                    for(halfx=0; halfx<2; halfx++)
                        {
55                     bvp = new BVPBlockProcessor();

                                bvp->AddArgument(height           = new BVPArgument(false));
                                bvp->AddArgument(deltaStride     = new BVPArgument(false));
                                bvp->AddArgument(deltaBase       = new BVPArgument(true));
                                bvp->AddArgument(targetBase      = new BVPArgument(true));
60                                bvp->AddArgument(sourceStride   = new BVPArgument(false));

```

```

5           bvp->AddArgument(source1Base      = new BVPArgument(true));

        //
        // Width is always sixteen pixels, so one vector of sixteen
10      unsigned eight bit elements,
        // height may vary, therefore it is an argument
        //
        bvp->SetDimension(1, height);

        //
15      // Four potential source blocks, B is one pel to the right,
      C one down and D right and down
        //
        bvp->AddSourceBlock(source1BlockA = new
BVPSourceBlock(source1Base,
20      sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));
        bvp->AddSourceBlock(source1BlockB = new
BVPSourceBlock(BVPPointer(source1Base, 1 + yuv),
sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));
        bvp->AddSourceBlock(source1BlockC = new
25      BVPSourceBlock(BVPPointer(source1Base, sourceStride, 1, 0),
sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));
        bvp->AddSourceBlock(source1BlockD = new
BVPSourceBlock(BVPPointer(source1Base, sourceStride, 1, 1 + yuv),
sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));

30      //
        // If we have error correction data, we need this source
      block as well
        //
35      if (delta)
        bvp->AddSourceBlock(deltaBlock   = new
BVPSourceBlock(deltaBase, deltaStride, BVPDataFormat(BVPDT_S16, 16),
0x10000));

40      //
        // The target block to write the data into
        //
        bvp->AddTargetBlock(targetBlock = new
BVPTargetBlock(targetBase, sourceStride, BVPDataFormat(BVPDT_U8, 16),
0x10000));

        //
45      // Load a source block base on the half pel settings
        //
50      bvp->AddInstruction(postMC = BuildBlockMerge(source1BlockA,
source1BlockB, source1BlockC, source1BlockD, halfx, halfy));

        if (delta)
        {
55      deltaData = new BVPDataLoad(deltaBlock);

        if (yuv)
        {
        //
60      // It is chroma data and we have error correction data.
      The u and v

```

```

5           // parts have to be interleaved, therefore we need the
merge instruction
//           .--(CONV S16)<--postMC
//           /           \
10          // <--(CONV U8)<--(ADD)           \
//           \           .--(SPLIT H)<-
//           \           /           \
//           \           --(MERGE OE)           \
//           \           /           \
//           \           .--(SPLIT T)<-
15          >--(LOAD delta)           /
//           /           \
//           /           \
//           bvp->AddInstruction
(
20          postCorrect =
new BVPDataConvert
(
BVPDT_U8,
new BVPDataOperation
(
BVPDO_ADD,
new BVPDataConvert
(
BVPDT_S16,
postMC
),
new BVPDataMerge
(
BVPDM_ODDEVEN,
new BVPDataSplit
(
BVPDS_HEAD,
deltaData
),
new BVPDataSplit
(
BVPDS_TAIL,
deltaData
)
45
)
)
)
);
50
}
else
{
//
// It is luma data with error correction
//
55
//           .--(CONV S16)<--postMC
//           /           \
// <--(CONV U8)<--(ADD)           \
//           \           .--(LOAD delta)
//           /
60
bvp->AddInstruction

```

```

5           (
10          postCorrect =
15          new BVPDataConvert
20          (
25          BVPDT_U8,
30          new BVPDataOperation
35          (
40          BVPDO_ADD,
45          new BVPDataConvert
50          (
55          BVPDT_S16,
60          postMC
        ),
      deltaData
    )
  );
}

//  

// Store into the target block  

//  

// (STORE targetBlock)<--...  

//  

bvp->AddInstruction
(
  new BVPDataStore
  (
    targetBlock,
    postCorrect
  )
);
else
{
//  

// No error correction data, so store motion result into  

target block
//  

// (STORE targetBlock)<--...
//  

bvp->AddInstruction
(
  new BVPDataStore
  (
    targetBlock,
    postMC
  )
);
}
BVPXMMXCodeConverter conv;

//  

// Convert graph into machine language  

//

```

```

5           compensationBlock[yuv][delta][halfy][halfx] = code =
conv.Convert(bvp);

10          //
11          // Get function entry pointer
12          //
13          compensation[yuv][delta][halfy][halfx] =
(CompensationCodeType)(code->GetCodeAddress());

15          //
16          // delete graph
17          //
18          delete bvp;
19          }
20      }
21  }

25  //
26  // build motion compensation routines for bidirectional prediction
27  //
28  for(yuv = 0; yuv<2; yuv++)
29  {
30      for(delta=0; delta<2; delta++)
31      {
32          for(halfly=0; halfly<2; halfly++)
33          {
34              for(halflx=0; halflx<2; halflx++)
35              {
36                  for(half2y=0; half2y<2; half2y++)
37                  {
38                      for(half2x=0; half2x<2; half2x++)
39                      {
40                          bvp = new BVPBlockProcessor();
41
42                          bvp->AddArgument(height           = new
43 BVPArgument(false));
44                          bvp->AddArgument(deltaStride     = new
45 BVPArgument(false));
46                          bvp->AddArgument(deltaBase       = new
47 BVPArgument(true));
48                          bvp->AddArgument(targetBase      = new
49 BVPArgument(true));
50                          bvp->AddArgument(sourceStride    = new
51 BVPArgument(false));
52                          bvp->AddArgument(source2Base    = new
53 BVPArgument(true));
54                          bvp->AddArgument(source1Base    = new
55 BVPArgument(true));
56
57                          bvp->SetDimension(1, height);
58
59                          //
60                          // We now have two source blocks, so we need eight
blocks for the half pel
61                          // prediction
62                          //

```

```

5           bvp->AddSourceBlock(source1BlockA = new
6             BVPSourceBlock(source1Base,
7               sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));
8               bvp->AddSourceBlock(source1BlockB = new
9             BVPSourceBlock(BVPPointer(source1Base, 1 + yuv),
10            sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));
11               bvp->AddSourceBlock(source1BlockC = new
12             BVPSourceBlock(BVPPointer(source1Base, sourceStride, 1, 0),
13            sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));
14               bvp->AddSourceBlock(source1BlockD = new
15             BVPSourceBlock(BVPPointer(source1Base, sourceStride, 1, 1 + yuv),
16            sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));
17               bvp->AddSourceBlock(source2BlockA = new
18             BVPSourceBlock(source2Base,
19            sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));
20               bvp->AddSourceBlock(source2BlockB = new
21             BVPSourceBlock(BVPPointer(source2Base, 1 + yuv),
22            sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));
23               bvp->AddSourceBlock(source2BlockC = new
24             BVPSourceBlock(BVPPointer(source2Base, sourceStride, 1, 0),
25            sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));
26               bvp->AddSourceBlock(source2BlockD = new
27             BVPSourceBlock(BVPPointer(source2Base, sourceStride, 1, 1 + yuv),
28            sourceStride, BVPDataFormat(BVPDT_U8, 16), 0x10000));

29           if (delta)
30             bvp->AddSourceBlock(deltaBlock = new
31               BVPSourceBlock(deltaBase, deltaStride, BVPDataFormat(BVPDT_S16, 16),
32               0x10000));

33           bvp->AddTargetBlock(targetBlock = new
34             BVPTargetBlock(targetBase, sourceStride, BVPDataFormat(BVPDT_U8, 16),
35               0x10000));

36           //
37           // Build bidirectional prediction from two
38           unidirectional predictions
39           //
40           //
41           //          .--BuildBlockMerge(source1Block*)
42           //
43           //          /
44           // <--(AVG)
45           //          \
46           //          '--BuildBlockMerge(source2Block*)
47           //
48           bvp->AddInstruction
49           (
50             postMC =
51               new BVPDataOperation
52               (
53                 BVPDO_AVG,
54                 BuildBlockMerge(source1BlockA, source1BlockB,
55                 source1BlockC, source1BlockD, half1x, half1y),
56                 BuildBlockMerge(source2BlockA, source2BlockB,
57                 source2BlockC, source2BlockD, half2x, half2y)
58               )
59           );

```

```

5
// Apply error correction, see unidirectional case
//
if (delta)
{
    deltaData = new BVPDataLoad(deltaBlock);

    if (yuv)
    {
        bvp->AddInstruction
        (
        postCorrect =
        new BVPDataConvert
        (
        BVPDT_U8,
        new BVPDataOperation
        (
        BVPDO_ADD,
        new BVPDataConvert
        (
        BVPDT_S16,
        postMC
        ),
        new BVPDataMerge
        (
        BVPDM_ODDEVEN,
        new BVPDataSplit
        (
        BVPDS_HEAD,
        deltaData
        ),
        new BVPDataSplit
        (
        BVPDS_TAIL,
        deltaData
        )
        )
        )
        )
    };
}
else
{
    bvp->AddInstruction
    (
    postCorrect =
    new BVPDataConvert
    (
    BVPDT_U8,
    new BVPDataOperation
    (
    BVPDO_ADD,
    new BVPDataConvert
    (
    BVPDT_S16,
    postMC
    ),

```

```

5                         deltaData
) )
) ;
}
10
bvp->AddInstruction
(
new BVPDataStore
(
targetBlock,
postCorrect
)
);
}
15
20
else
{
bvp->AddInstruction
(
new BVPDataStore
(
targetBlock,
postMC
)
);
}
25
30
BVPXMMXCodeConverter conv;

// 
// Translate routines
// 

bicompensationBlock[yuv][delta][halfly][half1x][half2y][half2x] =
code = conv.Convert(bvp);
40

bicompensation[yuv][delta][halfly][half1x][half2y][half2x] =
(BiCompensationCodeType)(code->GetCodeAddress());
45
        delete bvp;
    }
}
50
}
}
}
}
}
}

MPEG2MotionCompensation::~MPEG2MotionCompensation(void)
55
{
int yuv, delta, halfy, halfx, halfly, half1x, half2y, half2x;

//
// free all motion compensation routines
//
60
for(yuv = 0; yuv<2; yuv++)

```

```

5      {
10     for(delta=0; delta<2; delta++)
15       {
20         for(halfy=0; halfy<2; halfy++)
25           {
30             for(halfx=0; halfx<2; halfx++)
35               {
40                 delete compensationBlock[yuv][delta][halfy][halfx];
45               }
50             }
55           }
60         }
65       }
70     }
75   }
80 }
```

TABLE C

```

#ifndef BVPGENERIC_H
#define BVPGENERIC_H

45 #include "BVPList.h"

    //
    // Argument descriptor. An argument can be either a pointer or an
    integer used
50    // as a stride, offset or width/height value.
    //
    class BVPArgument{
    {
        public:
55        bool pointer;
        int index;
```

```

5         BVPArgument(bool pointer_)
6             : pointer(pointer_), index(0) {}
7     };

10    //
11    // Description of an integer value used as a stride or offset. An
12    integer value
13    // can be either an argument or a constant
14    //
15    class BVPInteger
16    {
17        public:
18            int           value;
19            BVPArgument * arg;
20
21            BVPInteger(void)
22                : value(0), arg(NULL) {}
23            BVPInteger(int value_)
24                : value(value_), arg(NULL) {}
25            BVPInteger(unsigned value_)
26                : value((int)value_), arg(NULL) {}
27            BVPInteger(BVPArgument * arg_)
28                : value(0), arg(arg_) {}

30            bool operator==(BVPInteger i2)
31            {
32                return arg ? (i2.arg == arg) : (i2.value == value);
33            }
34        };
35
36    //
37    // Description of a memory pointer used as a base for source and
38    target blocks.
39    // A pointer can be a combination of an pointer base, a constant
40    offset and
41    // a variable index with scaling
42    //
43    class BVPPointer
44    {
45        public:
46            BVPArgument * base;
47            BVPArgument * index;
48            int           offset;
49            int           scale;

50            BVPPointer(BVPArgument * base_)
51                : base(base_), index(NULL), offset(0), scale(0) {}

52            BVPPointer(BVPPointer base_, int offset_)
53                : base(base_.base), index(NULL), offset(offset_), scale(0) {}

54            BVPPointer(BVPPointer base_, BVPInteger index_, int scale_, int
55            offset_)
56                : base(base_.base), index(index_.arg), offset(offset_), scale(scale_) {}

57        };

```

```

5
//
// Base data formats for scalar types
//
enum BVPBaseDataFormat
10   {
      BVPDT_U8,      // Unsigned 8 bits
      BVPDT_U16,     // Unsigned 16 bits
      BVPDT_U32,     // Unsigned 32 bits
      BVPDT_S8,      // Signed 8 bits
15     BVPDT_S16,    // Signed 16 bits
      BVPDT_S32      // Signed 32 bits
    };

//
20   // Data forma descriptor for scalar and vector (multimedia simd)
types
    // Each data type is a combination of a base type and a vector size.
    // Scalar types are represented by a vector size of one.
    //
25   class BVPDataFormat
    {
public:
    BVPBaseDataFormat  format;
    int              num;

30   BVPDataFormat(BVPBaseDataFormat _format, int _num = 1)
      : format(_format), num(_num) {}

    BVPDataFormat(void)
35     : format(BVPDT_U8), num(0) {}

    BVPDataFormat(BVPDataFormat & f)
      : format(f.format), num(f.num) {}

    BVPDataFormat operator* (int times)
40     {return BVPDataFormat(format, num * times);}

    BVPDataFormat operator/ (int times)
      {return BVPDataFormat(format, num / times);}

45   int BitsPerElement(void) {static const int sz[] = {8, 16, 32, 8,
16, 32}; return sz[format];}
    int BitsPerChunk(void) {return BitsPerElement() * num;}
  };

50
//
// Operation codes for binary data operations that have the
// same operand type for both sources and the destination
//
55   enum BVPDataOperationCode
    {
      BVPDO_ADD,          // add with wraparound
      BVPDO_ADD_SATURATED, // add with saturation
      BVPDO_SUB,          // subtract with wraparound
50     BVPDO_SUB_SATURATED, // subtract with saturation
      BVPDO_MAX,          // maximum
    };

```

```

5      BVPDO_MIN,           // minimum
     BVPDO_AVG,           // average (includes rounding towards nearest)
     BVPDO_EQU,           // equal
     BVPDO_OR,            // binary or
     BVPDO_XOR,           // binary exclusive or
10    BVPDO_AND,           // binary and
     BVPDO_ANDNOT,        // binary and not
     BVPDO_MULL,          // multiply keep lower half
     BVPDO_MULH           // multiply keep upper half
   };

15
  //
  // Operations that extract a part of a data element
  //
enum BVPDataSplitCode
20  {
  BVPDS_HEAD,           // extract first half
  BVPDS_TAIL,           // extract second half
  BVPDS_ODD,            // extract odd elements
  BVPDS_EVEN            // extract even elements
};

25

  //
  // Operations that combine two data elements
  //
30 enum BVPDataMergeCode
  {
  BVPDM_UPPERLOWER,     // chain first and second operands
  BVPDM_ODDEVEN         // interleave first and second operands
};

35

  //
  // Node types in the data flow graph
  //
40 enum BVPIInstructionType
  {
  BVPIT_LOAD,           // load an element from a source block
  BVPIT_STORE,           // store an element into a source block
  BVPIT_CONSTANT,        // load a constant value
  BVPIT_SPLIT,           // split an element
45  BVPIT_MERGE,          // merge two elements
  BVPIT_CONVERT,         // perform a data conversion
  BVPIT_OPERATION         // simple binary data operation
};

50
  //
  // Descriptor of a data block. Contains a base pointer, a
  stride(pitch), a
  // format and an incrementor in vertical direction. The vertical
  block position
55  // can be incremented by a fraction or a multiple of the given pitch.
  //
class BVPBlock
  {
public:
  BVPPointer    base;
  BVPInteger    pitch;

```

```

5      BVPDataFormat format;
6      int          yscale;
7      int          index;

8      BVPBlock(BVPPointer _base, BVPInteger _pitch, BVPDataFormat
9      _format, int _yscale)
10     : base(_base), pitch(_pitch), format(_format), yscale(_yscale)
11     {}
12     };

13     //
14     // Descriptor of a source block
15     //
16     class BVPSourceBlock : public BVPBlock
17     {
18     public:
19         BVPSourceBlock(BVPPointer base, BVPInteger pitch, BVPDataFormat
20         format, int yscale)
21         : BVPBlock(base, pitch, format, yscale) {}
22     };

23     //
24     // Descriptor of a target block
25     //
26     class BVPTargetBlock : public BVPBlock
27     {
28     public:
29         BVPTargetBlock(BVPPointer base, BVPInteger pitch, BVPDataFormat
30         format, int yscale)
31         : BVPBlock(base, pitch, format, yscale) {}
32     };

33     class BVPDataSource;
34     class BVPDataDrain;
35     class BVPDataInstruction;

36     //
37     // Source connection element of a node in the data flow graph. Each
38     // node in
39     // the graph contains one or none source connection. A source
40     // connection is
41     // the output of a node in the graph. Each source connection can be
42     // connected
43     // to any number of drain connections in other nodes of the flow
44     // graph. The
45     // source is the output side of a node.
46     //

47     class BVPDataSource
48     {
49     public:
50         BVPDataFormat      format;
51         BVPList<BVPDataDrain *>   drain;

52         BVPDataSource(BVPDataFormat _format) : format(_format) {}

53         virtual void AddInstructions(BVPList<BVPDataInstruction *> &
54         instructions) {}

```

```

5      virtual BVPDataInstruction * ToInstruction(void) {return NULL;}
6      };
7
8      // Drain connection element of a node in the data flow graph.  Each
9      node
10     // can have none, one or two drain connections (but only one drain
11     object
12     // to represent both).  Each drain connects to exactly one source on
13     the
14     // target side.  As eachnode can have only two inputs, each drain is
15     connected
16     // (through the node) with two sources.  The drain is the input side
17     of a
18     // node.
19     //
20     class BVPDataDrain
21     {
22     public:
23         BVPDataSource           * source1;
24         BVPDataSource           * source2;
25
26         BVPDataDrain(BVPDataSource * source1_, BVPDataSource * source2_ =
27             NULL)
28             : source1(source1_), source2(source2_) {}
29
30         virtual BVPDataInstruction * ToInstruction(void) {return NULL;}
31     };
32
33     // Each node in the graph represents one abstract instruction.  It
34     has an
35     // instruction type that describes the operation of the node.
36     //
37     class BVPDataInstruction
38     {
39     public:
40         BVPInstructionType type;
41         int                 index;
42
43         BVPDataInstruction(BVPInstructionType type_)
44             : type(type_), index(-1) {}
45
46         virtual ~BVPDataInstruction(void) {}
47
48         virtual void AddInstructions(BVPList<BVPDataInstruction *> &
49             instructions);
50         virtual void GetOperationBits(int & minBits, int & maxBits);
51
52         virtual BVPDataFormat GetInputFormat(void) = 0;
53         virtual BVPDataFormat GetOutputFormat(void) = 0;
54
55         virtual BVPDataSource * ToSource(void) {return NULL;}
56         virtual BVPDataDrain * ToDrain(void) {return NULL;}
57     };
58
59     //
60

```

```

5   // Node that is a data source
6   //
7   class BVPDataSourceInstruction : public BVPDataInstruction, public
8   BVPDataSource
9   {
10  public:
11    BVPDataSourceInstruction(BVPInstructionType type_, BVPDataFormat
12    format_)
13      : BVPDataInstruction(type_), BVPDataSource(format_) {}

14  void GetOperationBits(int & minBits, int & maxBits);

15  BVPDataFormat GetOutputFormat(void) {return format;}
16  BVPDataFormat GetInputFormat(void) {return format;}

17  BVPDataInstruction * ToInstruction(void) {return this;}
18  BVPDataSource * ToSource(void) {return this;}
19 }

20  //

21  // Node that is a data source and has one or two sources connected to
22  its drain
23  //
24  class BVPDataSourceDrainInstruction : public BVPDataSourceInstruction,
25  public BVPDataDrain
26  {
27  public:
28    BVPDataSourceDrainInstruction(BVPInstructionType type_,
29    BVPDataFormat format_, BVPDataSource * source1_)
30      : BVPDataSourceInstruction(type_, format_),
31        BVPDataDrain(source1_)
32          {source1->drain.Insert(this);}

33    BVPDataSourceDrainInstruction(BVPInstructionType type_,
34    BVPDataFormat format_, BVPDataSource * source1_, BVPDataSource *
35    source2_)
36      : BVPDataSourceInstruction(type_, format_),
37        BVPDataDrain(source1_, source2_)
38          {source1->drain.Insert(this);source2->drain.Insert(this);}
39      };

40  //

41  // Instruction to load data from a source block
42  //
43  class BVPDataLoad : public BVPDataSourceInstruction
44  {
45  public:
46    BVPSourceBlock * block;
47    int offset;

48    BVPDataLoad(BVPSourceBlock * block_, int offset_ = 0)
49      : BVPDataSourceInstruction(BVPI_T_LOAD, block_->format),
50        block(block_), offset(offset_) {}

51  void AddInstructions(BVPLIST<BVPDataInstruction *> & instructions);
52  };

53  //

54

```

```

5     // Instruction to store data into a target block
    //
class BVPDataStore : public BVPDataInstruction, public BVPDataDrain
{
public:
10    BVPTargetBlock * block;

    BVPDataStore(BVPTargetBlock * block_, BVPDataSource * source)
        : BVPDataInstruction(BVPIT_STORE), BVPDataDrain(source),
      block(block_)
15    {source->drain.Insert(this);}

    void AddInstructions(BVPList<BVPDataInstruction *> & instructions);

    BVPDataFormat GetOutputFormat(void) {return source1->format;}
20    BVPDataFormat GetInputFormat(void) {return source1->format;}

    BVPDataInstruction * ToInstruction(void) {return this;}
    BVPDataDrain * ToDrain(void) {return this;}
};

25
// 
// Instruction to load a constant
//
class BVPDataConstant : public BVPDataSourceInstruction
30 {
public:
    int value;

    BVPDataConstant(BVPDataFormat format, int value_)
35     : BVPDataSourceInstruction(BVPIT_CONSTANT, format),
      value(value_) {}
};

40
// 
// Instruction to split a data element
//
class BVPDataSplit : public BVPDataSourceDrainInstruction
{
public:
45    BVPDataSplitCode code;

    BVPDataSplit(BVPDataSplitCode code_, BVPDataSource * source)
        : BVPDataSourceDrainInstruction(BVPIT_SPLIT, source->format / 2,
      source), code(code_) {}

50
    void AddInstructions(BVPList<BVPDataInstruction *> & instructions);

    BVPDataDrain * ToDrain(void) {return this;}

55    BVPDataFormat GetInputFormat(void) {return source1->format;}
};

60
// 
// Instruction to merge two data elements
//
class BVPDataMerge : public BVPDataSourceDrainInstruction

```

```

5      {
6      public:
7          BVPDataMergeCode code;
8
9          BVPDataMerge(BVPDataMergeCode code_, BVPDataSource * source1_,
10         BVPDataSource * source2_)
11             : BVPDataSourceDrainInstruction(BVPIT_MERGE, source1_->format *
12             2, source1_, source2_), code(code_) {}
13
14     void AddInstructions(BVPList<BVPDataInstruction *> & instructions);
15
16     BVPDataDrain * ToDrain(void) {return this;}
17
18     BVPDataFormat GetInputFormat(void) {return source1->format;}
19
20 };
21
22 /**
23  // Instruction to convert the basic vector elements of an data
24  element into
25  // a different format (eg. from signed 16 bit to unsigned 8 bits).
26  //
27  class BVPDataConvert : public BVPDataSourceDrainInstruction
28  {
29  public:
30      BVPDataConvert(BVPBaseDataFormat target, BVPDataSource * source)
31          : BVPDataSourceDrainInstruction(BVPIT_CONVERT,
32          BVPDataFormat(target, source->format.num), source) {}
33
34      void AddInstructions(BVPList<BVPDataInstruction *> & instructions);
35
36      BVPDataDrain * ToDrain(void) {return this;}
37
38      BVPDataFormat GetInputFormat(void) {return source1->format;}
39
40 /**
41  // Basic data manipulation operation from two sources to one drain.
42  //
43  class BVPDataOperation : public BVPDataSourceDrainInstruction
44  {
45  public:
46      BVPDataOperationCode code;
47
48      BVPDataOperation(BVPDataOperationCode code_, BVPDataSource *
49      source1_, BVPDataSource * source2_)
50          : BVPDataSourceDrainInstruction(BVPIT_OPERATION, source1_-
51          >format, source1_, source2_), code(code_) {}
52
53      void AddInstructions(BVPList<BVPDataInstruction *> & instructions);
54
55      BVPDataDrain * ToDrain(void) {return this;}
56
57 /**
58  // Descriptor for one image block processing routine. It contains
59  the arguments, the

```

```

5      // size and the dataflow graph.  On destruction of the block
processor all argument,
// blocks and instructions are also deleted.
//
10    class BVPBlockProcessor
11    {
12    public:
13      BVPInteger  width;
14      BVPInteger  height;

15      BVPList<BVPBlock *> blocks;
16      BVPList<BVPDataInstruction *> instructions;
17      BVPList<BVPArgument *> args;

18      BVPBlockProcessor(void)
19      {
20      }

21      ~BVPBlockProcessor(void);

22      //
23      // Add an argument to the list of arguments.  Please note that
the arguments
// are added in the reverse order of the c-calling convention.
24      //
25      void AddArgument(BVPArgument * arg)
26      {
27        arg->index = args.Num();
28        args.Insert(arg);
29      }

30      //
31      // Set the dimension of the operation rectangle.  The width and
height can
// either be constants or arguments to the routine.
32      //
33      void SetDimension(BVPInteger width, BVPInteger height)
34      {
35        this->width = width;
36        this->height = height;
37      }

38      //
39      // Add a source block to the processing
40      //
41      void AddSourceBlock(BVPSourceBlock * block)
42      {
43        block->index = blocks.Num();
44        blocks.Insert(block);
45      }

46      //
47      // Add a target block to the processing
48      //
49      void AddTargetBlock(BVPTargetBlock * block)
50      {
51        block->index = blocks.Num();
52      }

```

```
5         blocks.Insert(block);
    }

    //
    // Add an instruction to the dataflow graph. All referenced
10   instructions
        // will also be added to the graph if they are not yet part of
it.
    //
15   void AddInstruction(BVPDataInstruction * ins)
    {
        ins->AddInstructions(instructions);
    }

    void GetOperationBits(int & minBits, int & maxBits);
20 }
```

#endif

25 Although the invention is described herein with reference to the preferred embodiment, one skilled in the art will readily appreciate that other applications may be substituted for those set forth herein without departing from the spirit and scope of the present invention. Accordingly, the invention should only be limited 30 by the claims included below.

Claims

1. An apparatus for generating computer assembly code, comprising:
 - an abstract routine generator for receiving a data stream comprising a
 - 10 multimedia routine and for outputting a generic abstract representation thereof;
 - and
 - a translator for said abstract routine generator for receiving said abstract representation and for outputting processor specific code for processing
 - 15 multimedia input data.
2. The apparatus of Claim 1, wherein said abstract routine generator builds an abstract routine during runtime.
3. The apparatus of Claim 1, wherein said abstract routine generator builds an abstract routine in the form of a graph.
- 20
4. The apparatus of Claim 1 wherein said multimedia data comprise SIMD input data.
- 25
5. The apparatus of Claim 1, wherein said multimedia data comprise image input data.

5 6. The apparatus of Claim 1, wherein said multimedia data comprise audio input
data.

7. The apparatus of Claim 3, wherein said graph is input to said translator.

10 8. The apparatus of Claim 3, wherein the output of said translator is in assembly
code.

15 9. The apparatus of Claim 1, wherein said translator's configuration can be
changed by use of a dynamic library link.

10. The apparatus of Claim 1, wherein said processor-specific code
performs any of the operations of add, sub, multiply, average, maximum,
minimum, compare, and, or, xor, pack, unpack, and merge on said input data.

20 11. The apparatus of Claim 3, wherein said graph is a function of any of source
block, target block, change in the block, color, stride, change in stride, display
block, and spatial filtering.

12. A method for generating assembly code, comprising:

25 providing an abstract routine generator for generating a generic abstract
representation of an input stream, and input comprising multimedia a routine; and

5 providing a translator for receiving said abstract representation from said
abstract routine generator and for outputting processor-specific code for
processing multimedia input data.

13. The method of Claim 12, wherein said abstract routine generator builds the
10 abstract routine during runtime.

14. The method of Claim 13, wherein said abstract routine is a graph.

15. The method of Claim 12, wherein said multimedia input data comprise
15 SIMD data.

16. The method of Claim 12, said multimedia input data comprise image data.

17. The method of Claim 12, wherein said multimedia input data comprise
20 audio data.

18. The method of claim 14, wherein said graph is input to said translator.

19. The method of claim 12, wherein the output of said translator is assembly
25 code.

- 5 20. The method of Claim 12, wherein said processor-specific code performs
any of the operations of add, sub, multiply, average, maximum, minimum,
compare, and, or, xor, pack, unpack, and merge on said multimedia input data.
- 10 21. The method of Claim 14, wherein said graph is a function of any of source
block, target block, change in the block, color, stride, change in stride, display
block, and spatial filtering.
- 15 22. The method of Claim 12, wherein said translator can be changed by use of
a dynamic library link.

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Abstract

A method and apparatus for processing multimedia instruction enhanced data by the use of an abstract routine generator and a translator. The abstract routine generator takes the multimedia instruction enhanced data and generates abstract routines to compile the multimedia instruction enhanced data. The 10 output of the abstract generator is an abstract representation of the multimedia instruction enhanced data. The translator then takes the abstract representation and produces code for processing.

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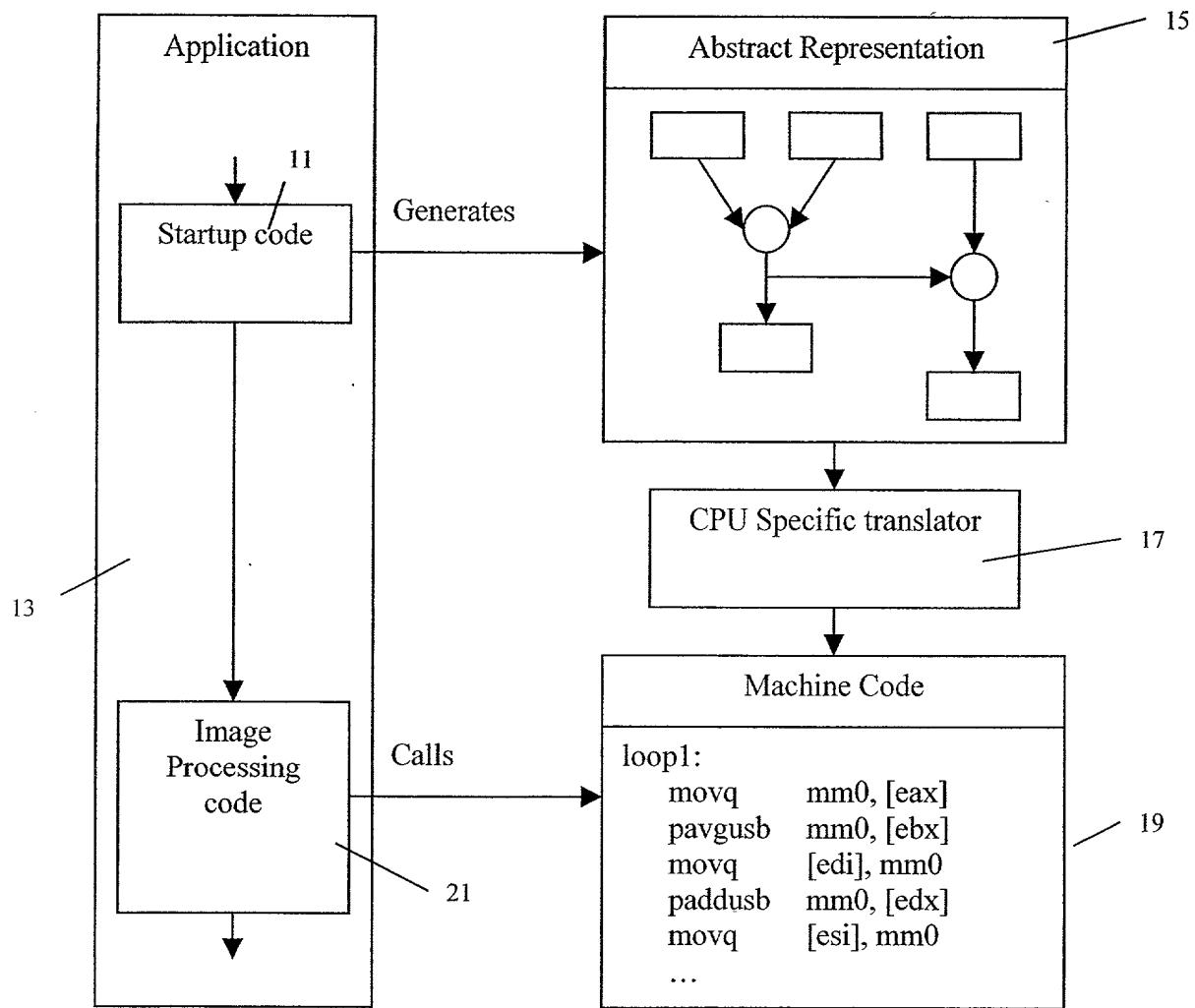


Fig. 1

DECLARATION FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name;

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**ON THE FLY GENERATION OF MULTIMEDIA CODE FOR
IMAGE PROCESSING**

the specification of which (check one) is attached hereto, or _____ was filed on _____ as Application Serial No. _____ and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

=====

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Priority Claimed
Yes No

Number Country Day/Month/Year Filed

Number Country Day/Month/Year Filed

=====

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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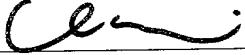
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I hereby claim the benefit under Title 35, United States code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Ser. No. _____ Filing Date _____ Status: Patented, Pending, Abandoned _____

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor: ULRICH SIGMUND

Inventor's signature 

06/30/2000

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